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[54] **METHOD OF MAKING PERIPHERAL LOW INDUCTANCE INTERCONNECTS WITH REDUCED CONTAMINATION**

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[51] **Int. Cl.⁷** **B05D 5/12; B32B 3/00**

[52] **U.S. Cl.** **428/209; 427/98; 427/307; 427/357; 427/97; 428/901**

[58] **Field of Search** **427/97, 98, 357, 427/307; 428/901, 209**

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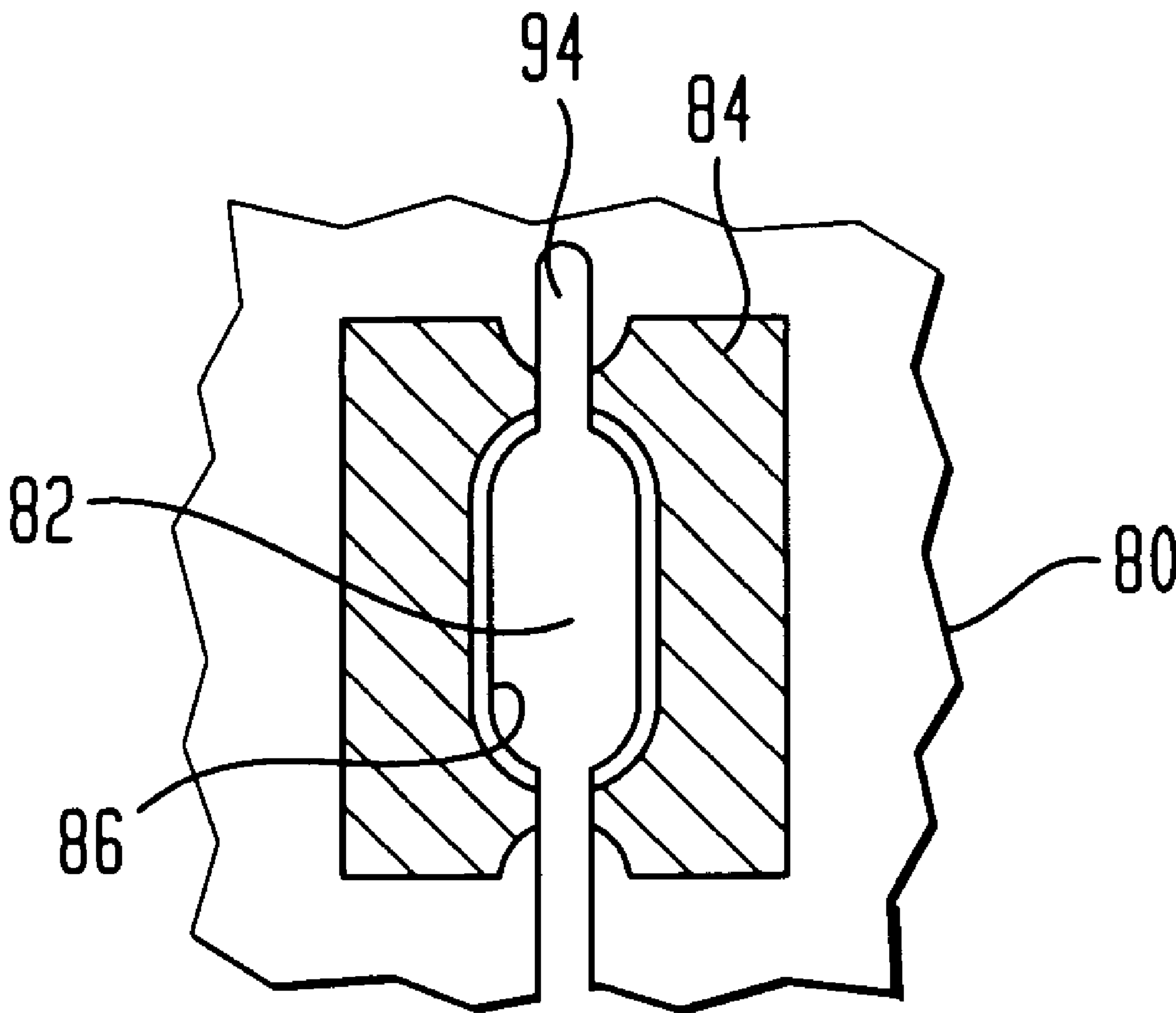
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Primary Examiner—Shrive Beck
Assistant Examiner—Paul D. Strain

[57] **ABSTRACT**

A method for making a circuit device having at least one peripheral interconnect for electrically connecting the device to another circuit device on a motherboard, includes forming at least one opening in a substrate, the opening having an inner surface extending between first and second major surfaces of the substrate. The inner surface of the opening and portions of the major surfaces adjacent the opening are coated with electrically conductive material. Electrically conductive material is removed from opposing regions of the inner surface of the opening prior to plating and then, after plating, the substrate is cut in a line extending across opposing regions to expose the coated and plated inner surface as the peripheral electrical interconnect. The method produces interconnects with reduced contamination by conductive particulates.

13 Claims, 5 Drawing Sheets



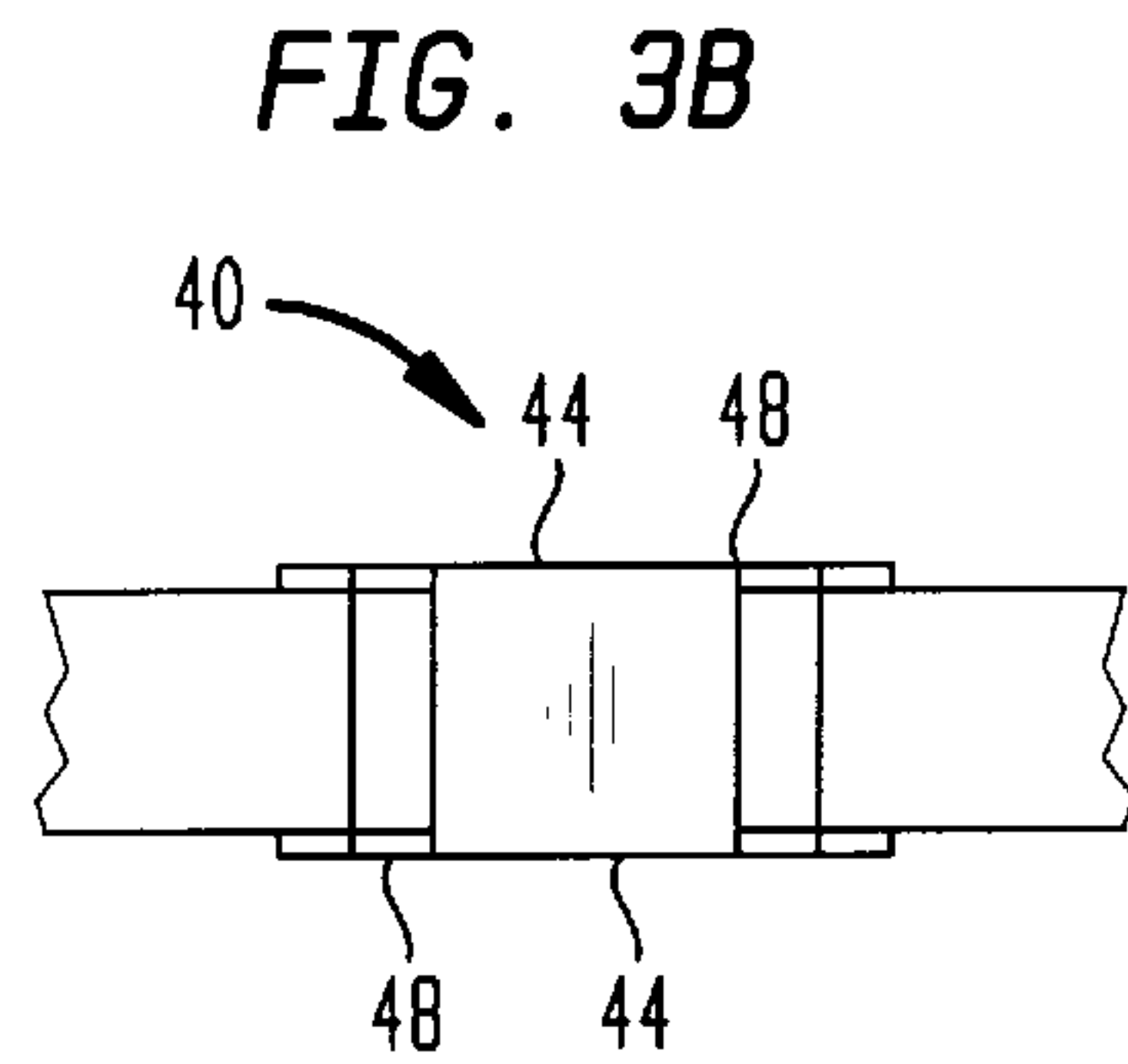
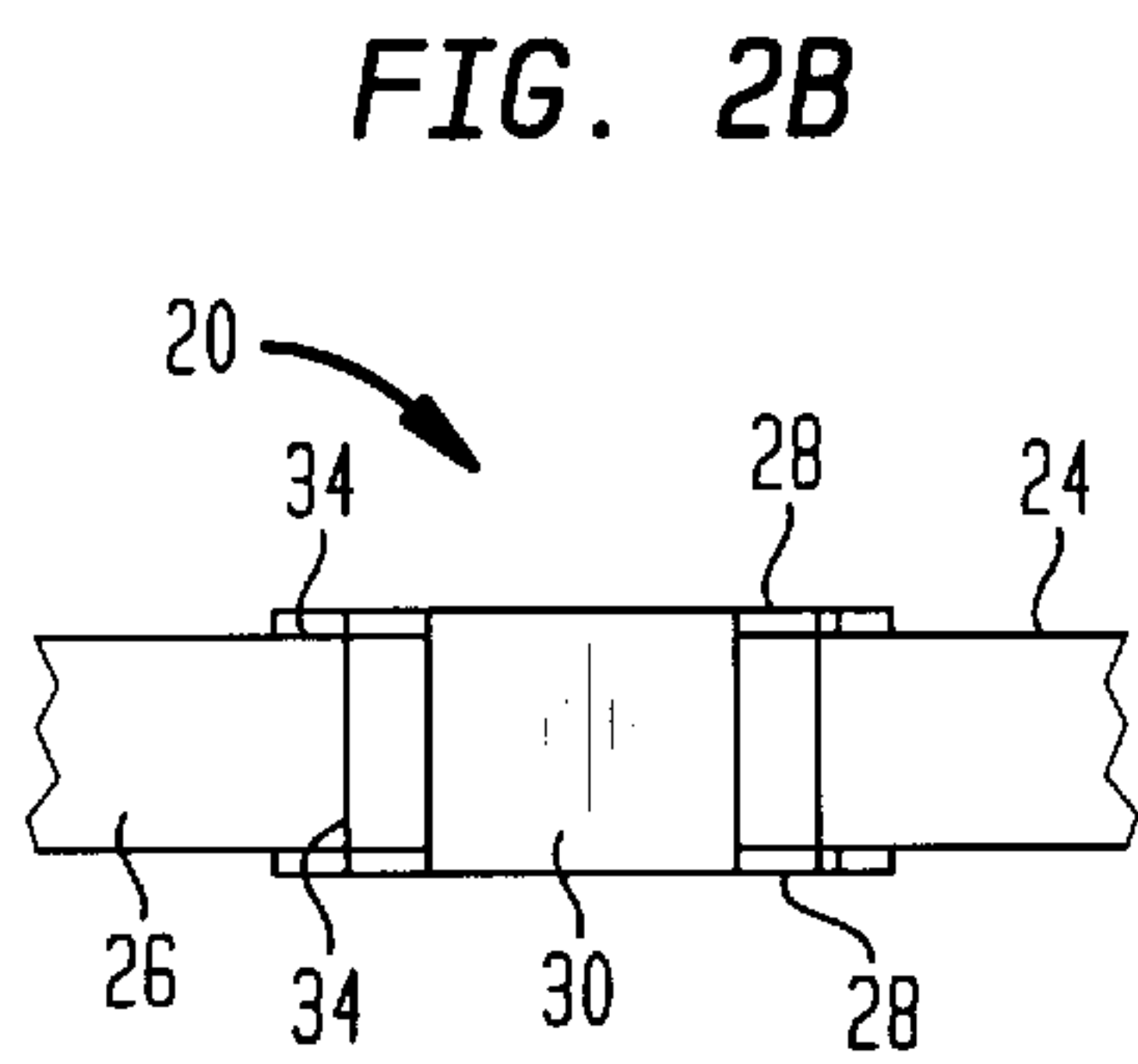
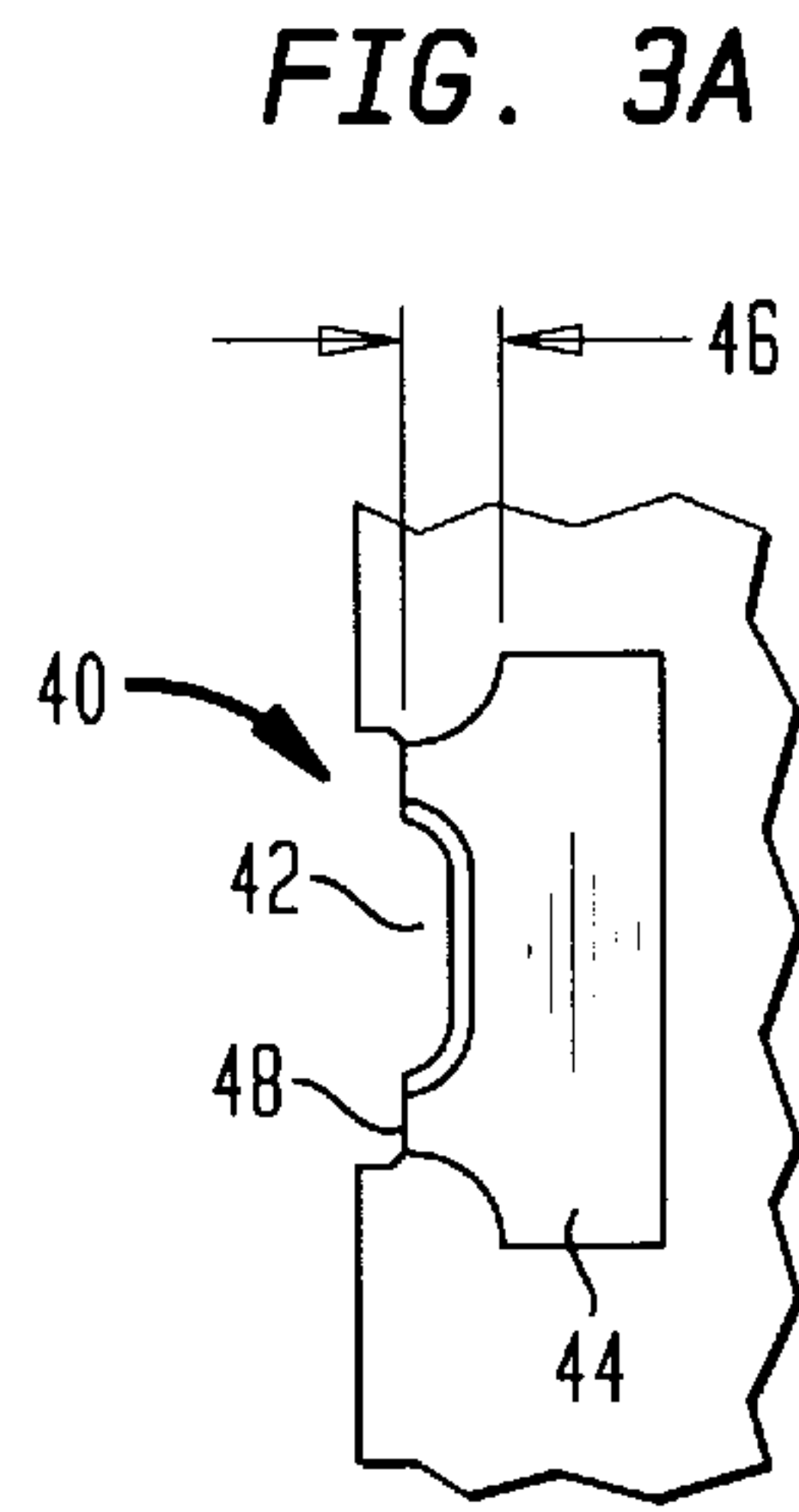
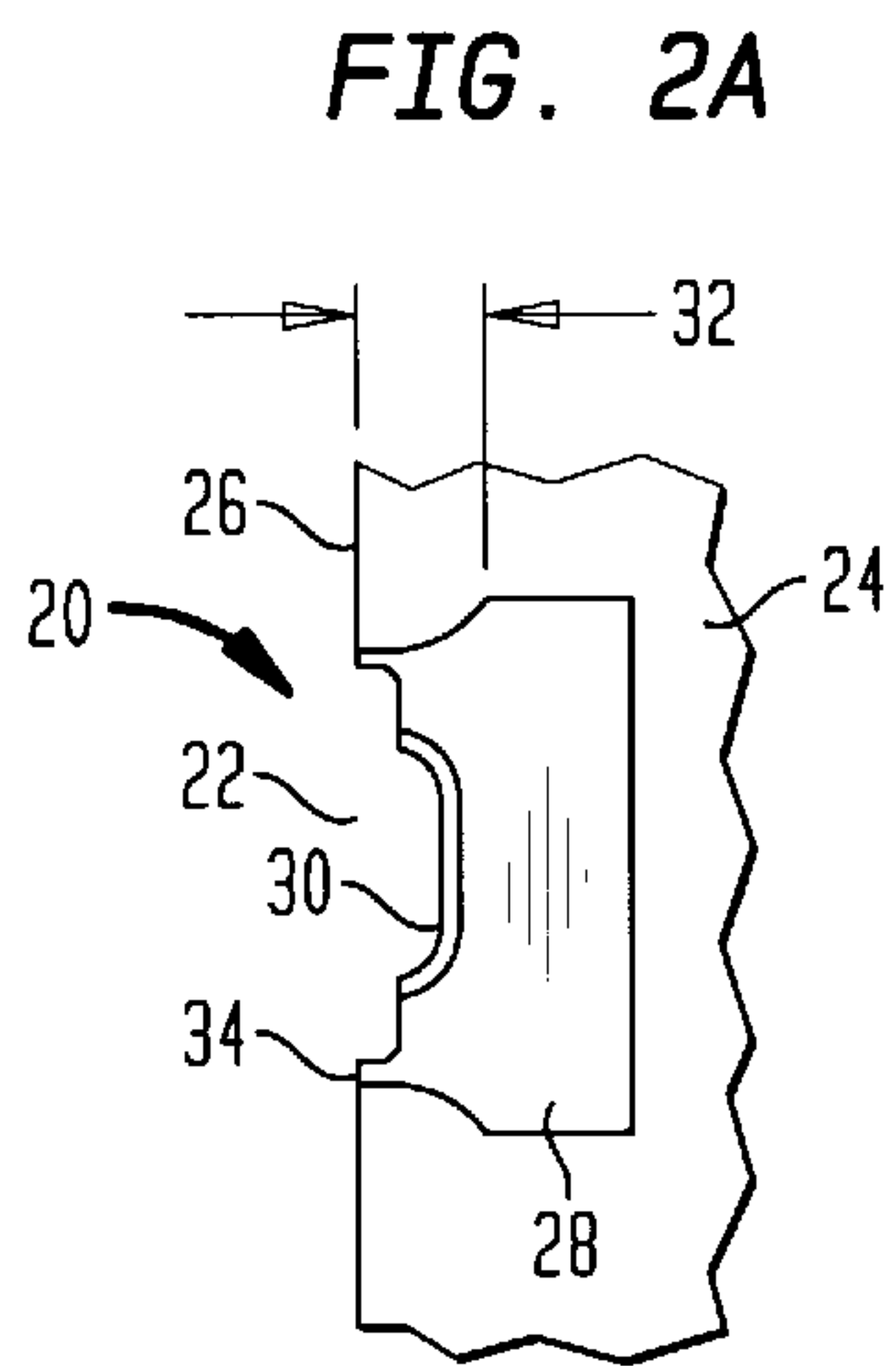
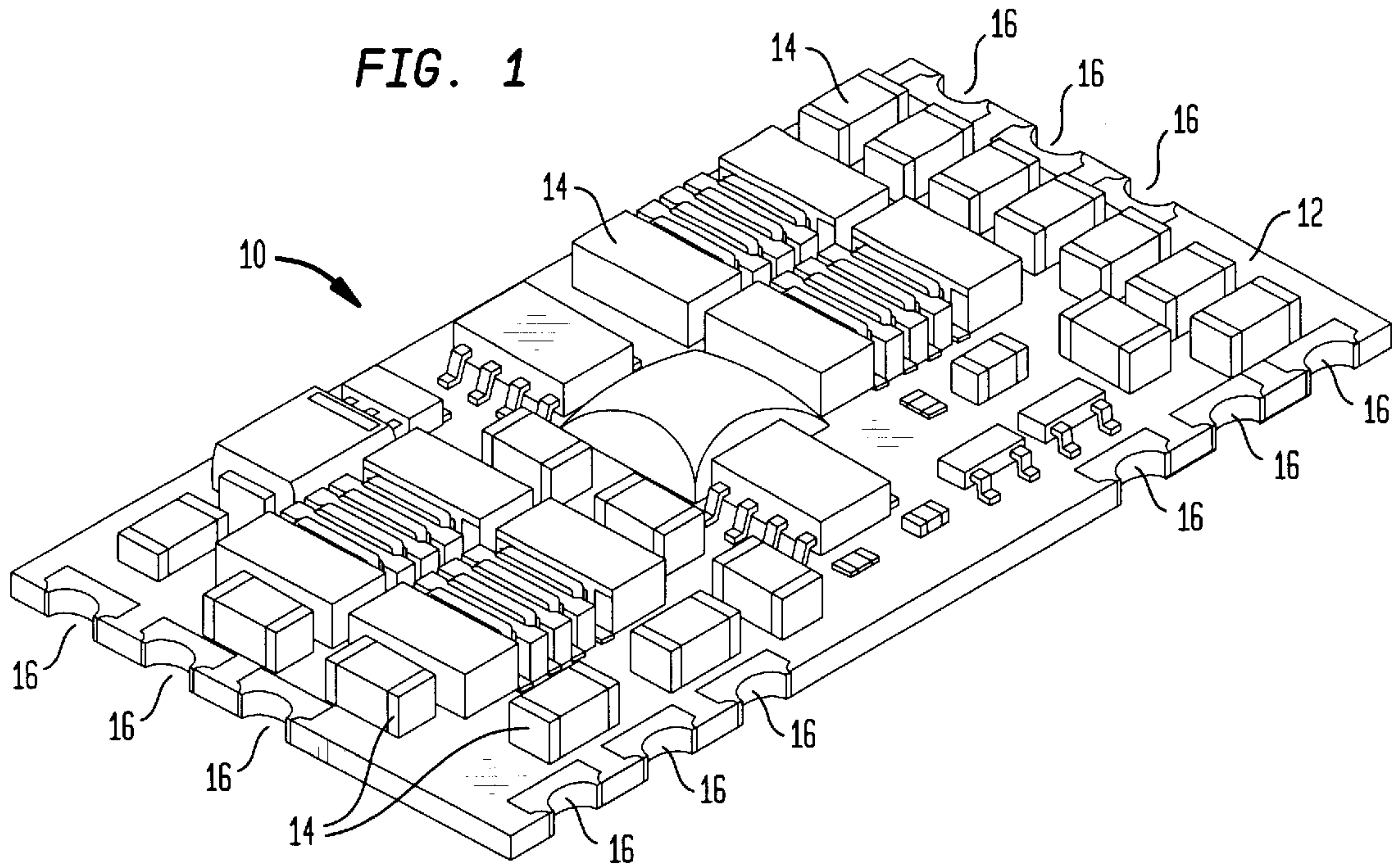


FIG. 4A

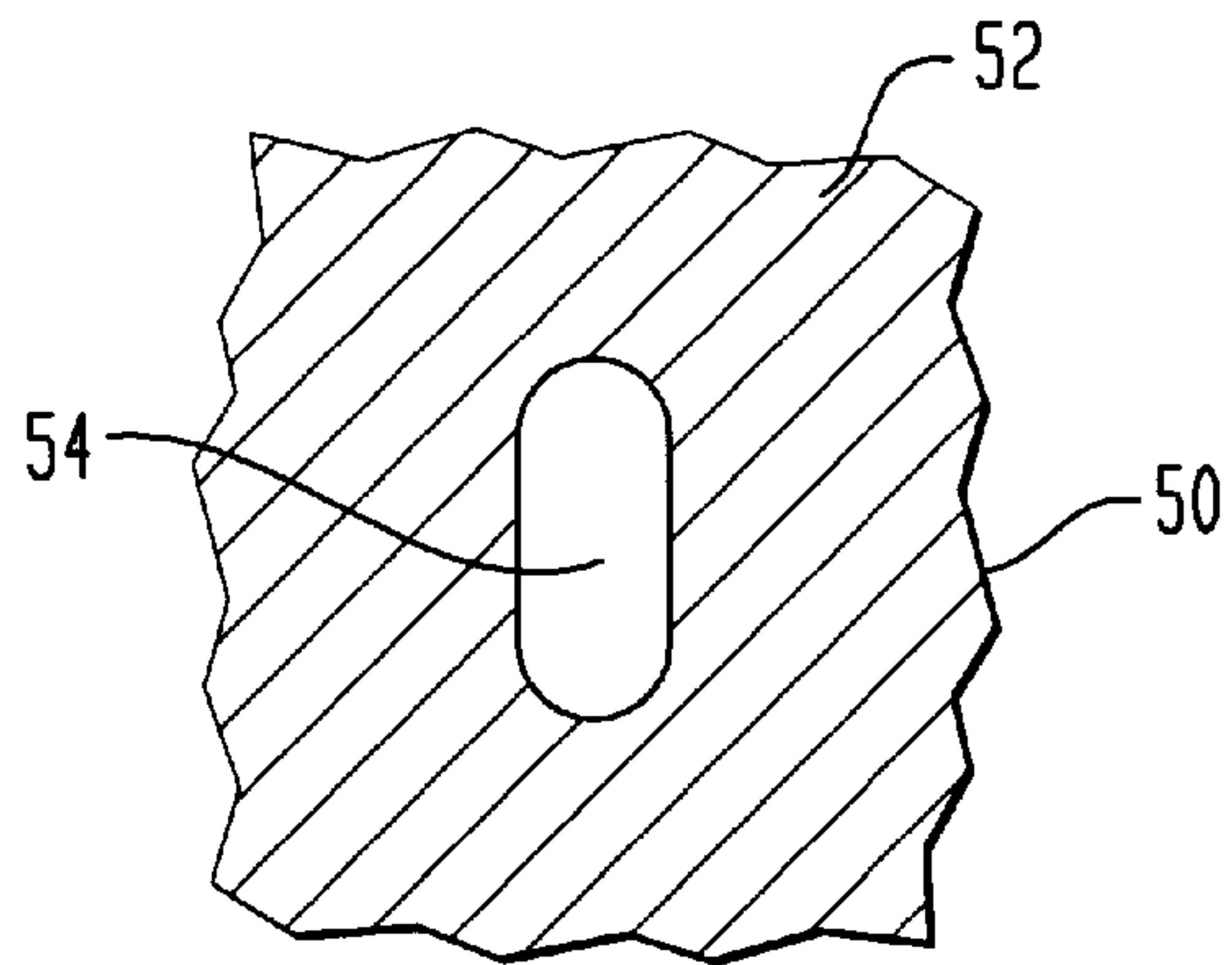


FIG. 4B

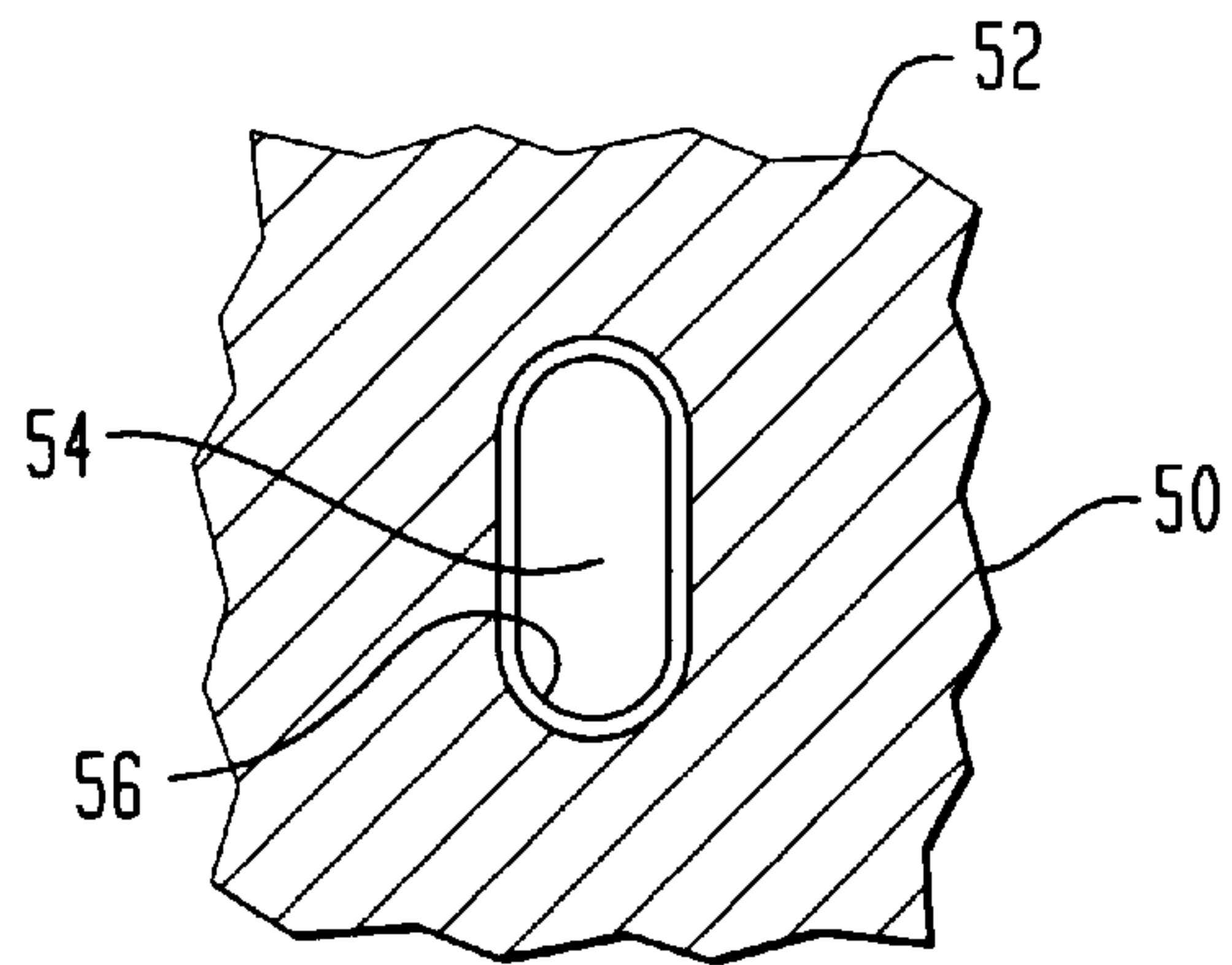


FIG. 4C

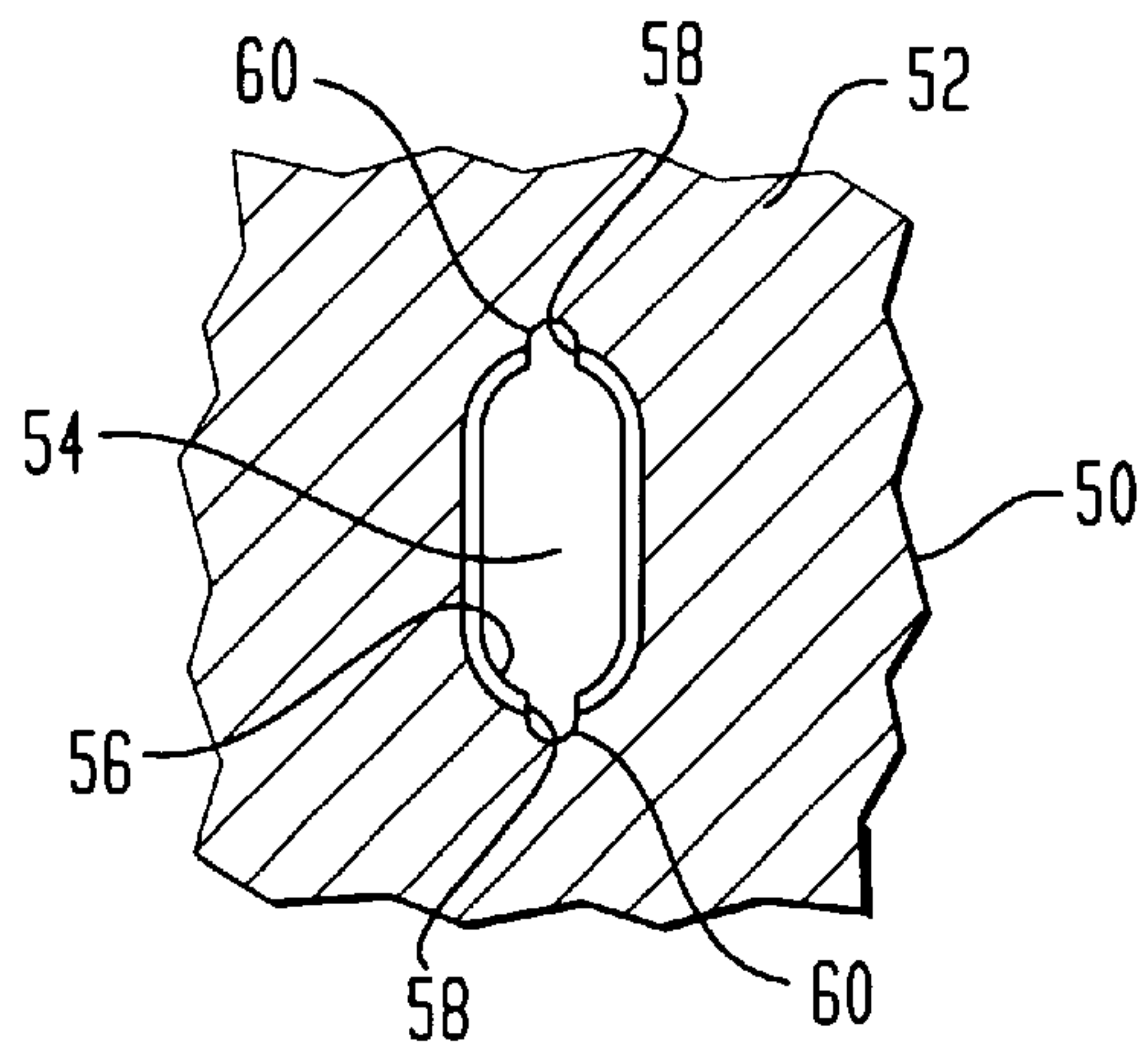


FIG. 4D

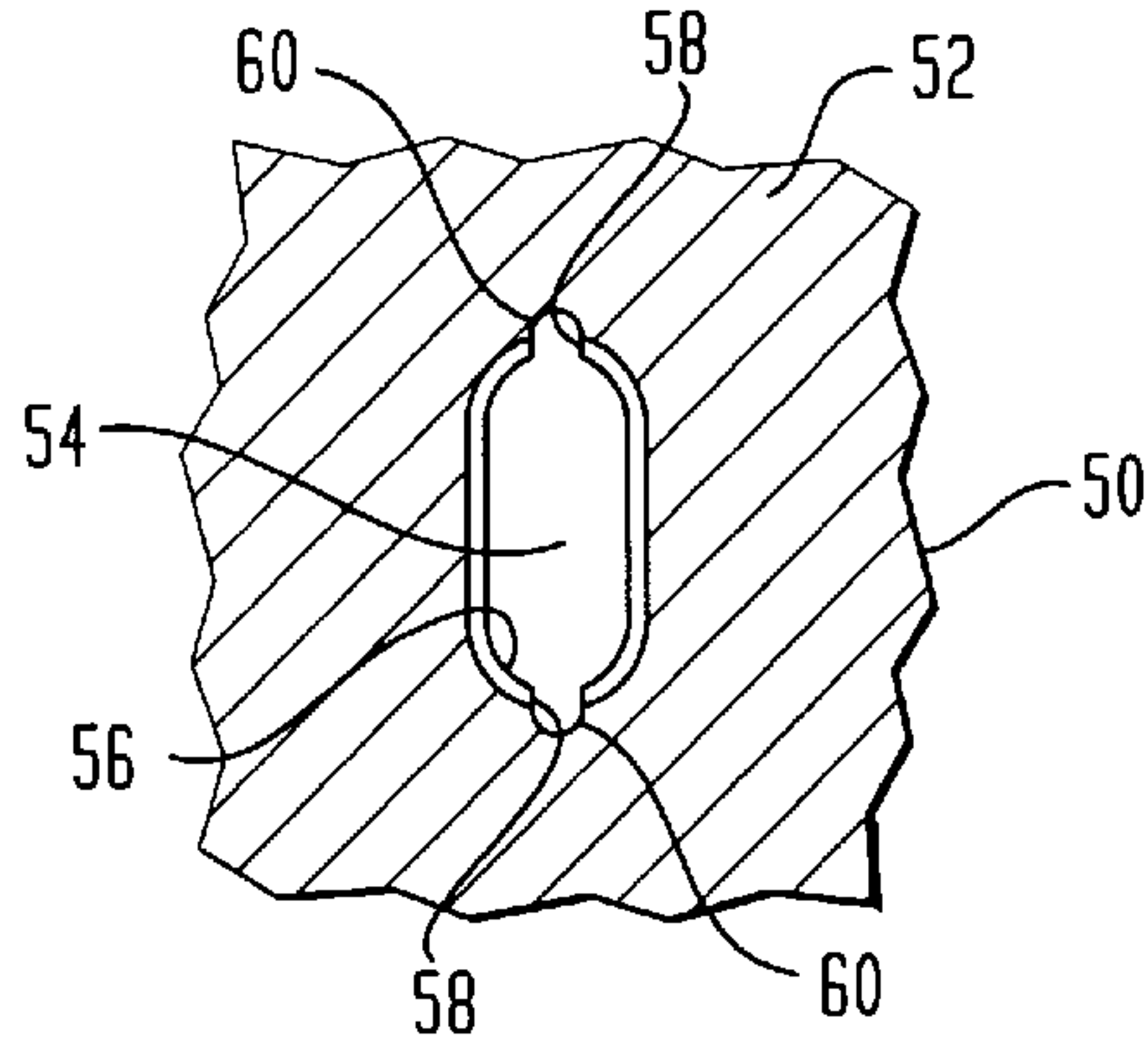


FIG. 4E

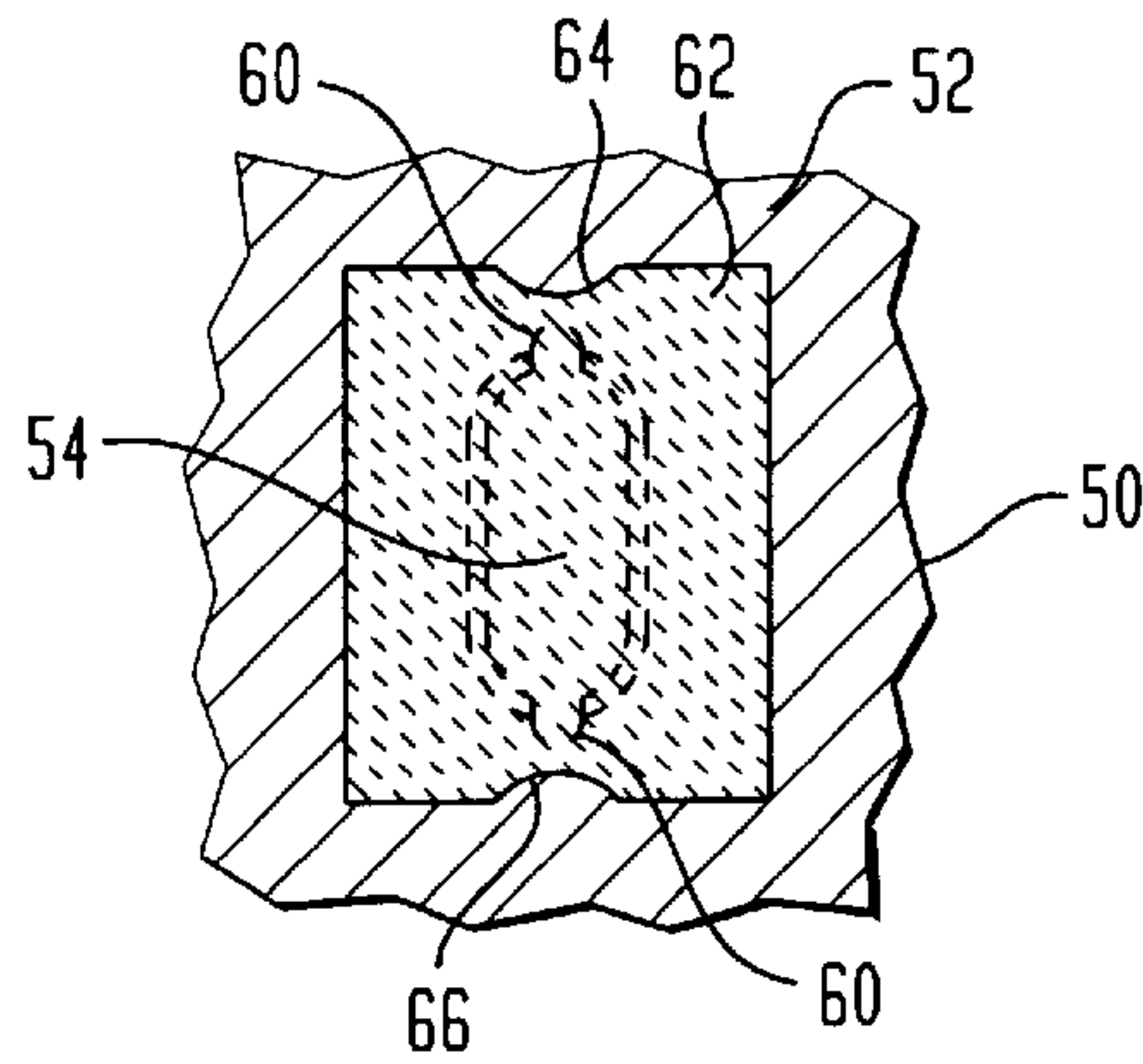


FIG. 4F

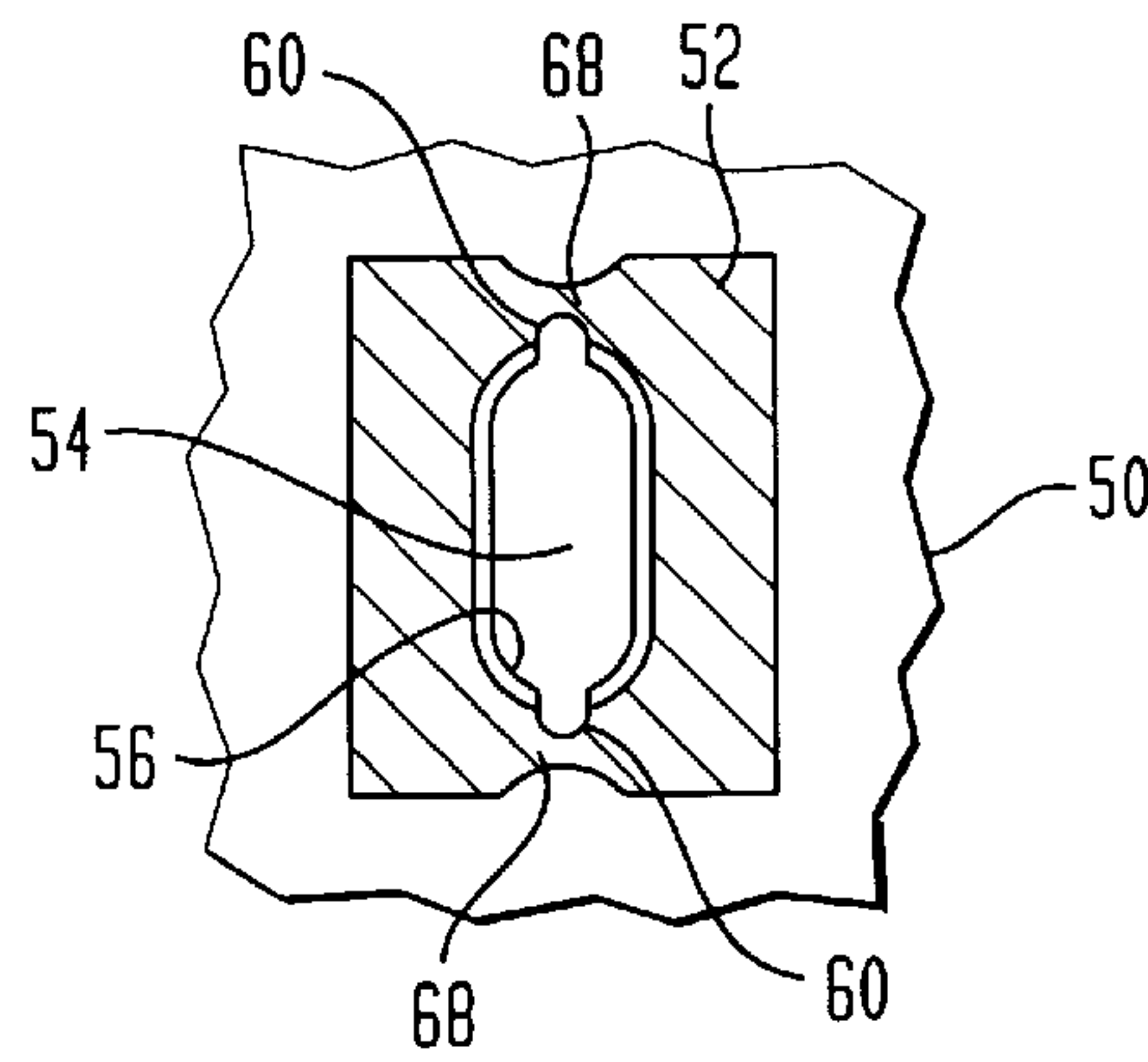


FIG. 4G

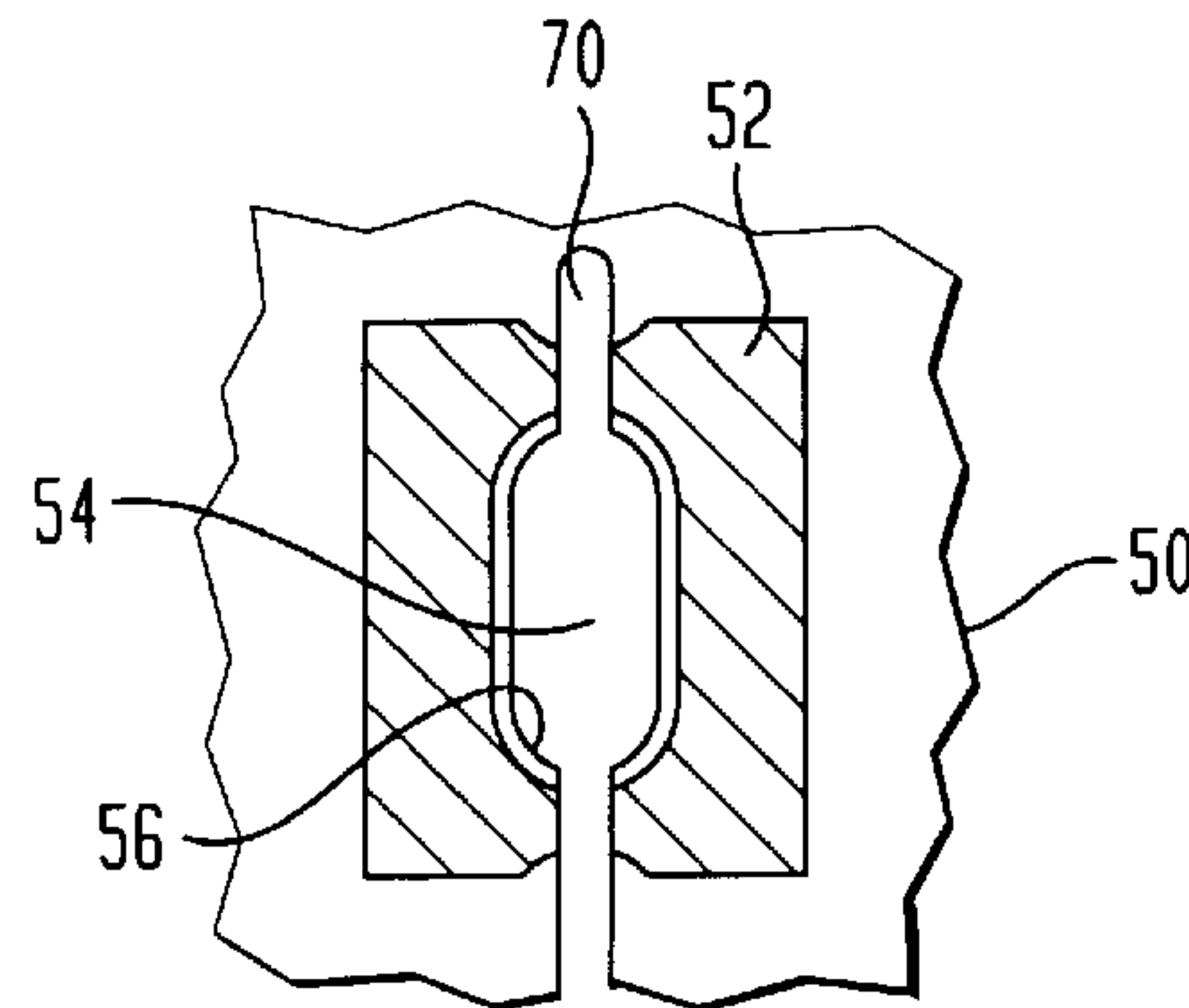


FIG. 5A

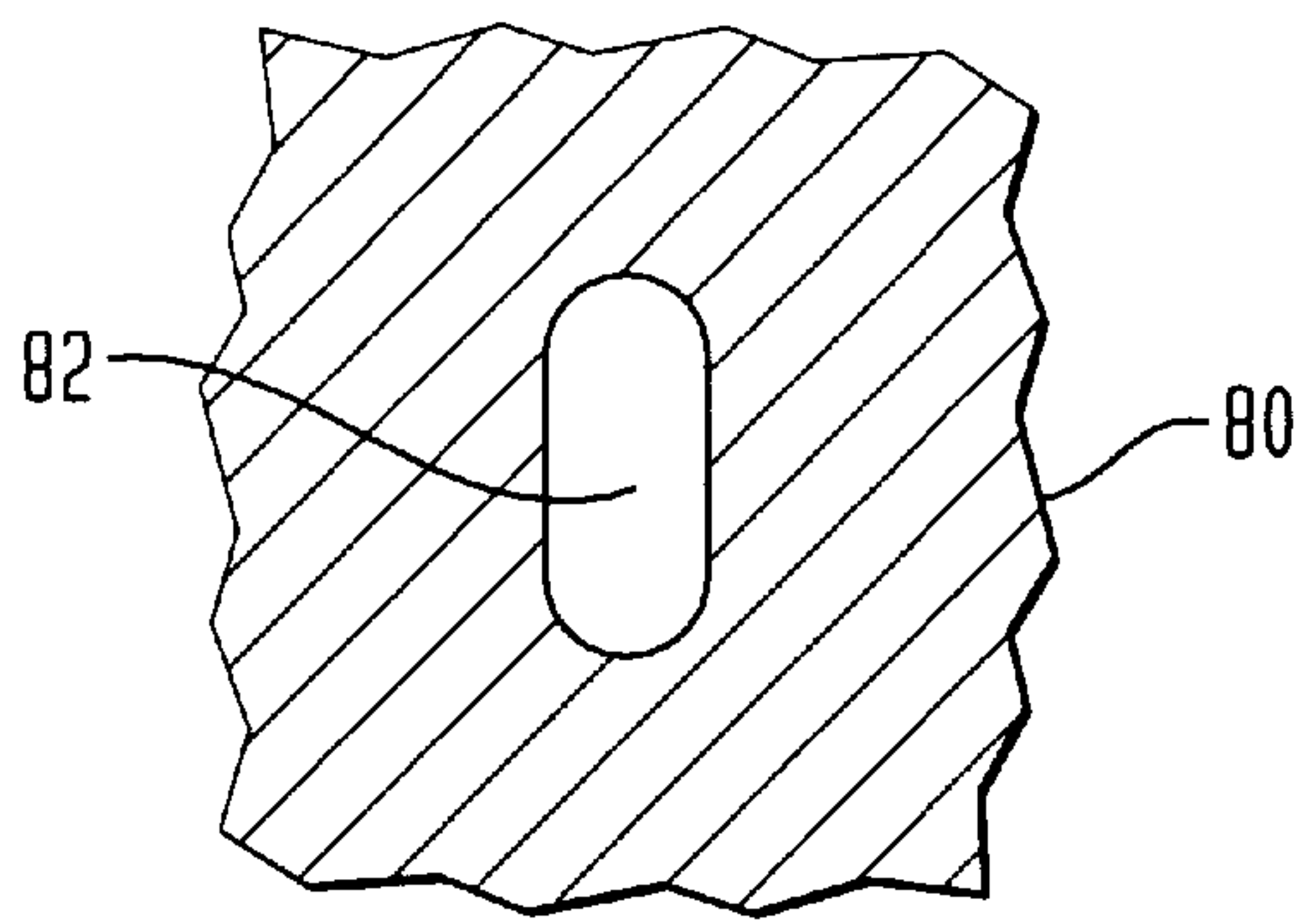


FIG. 5B

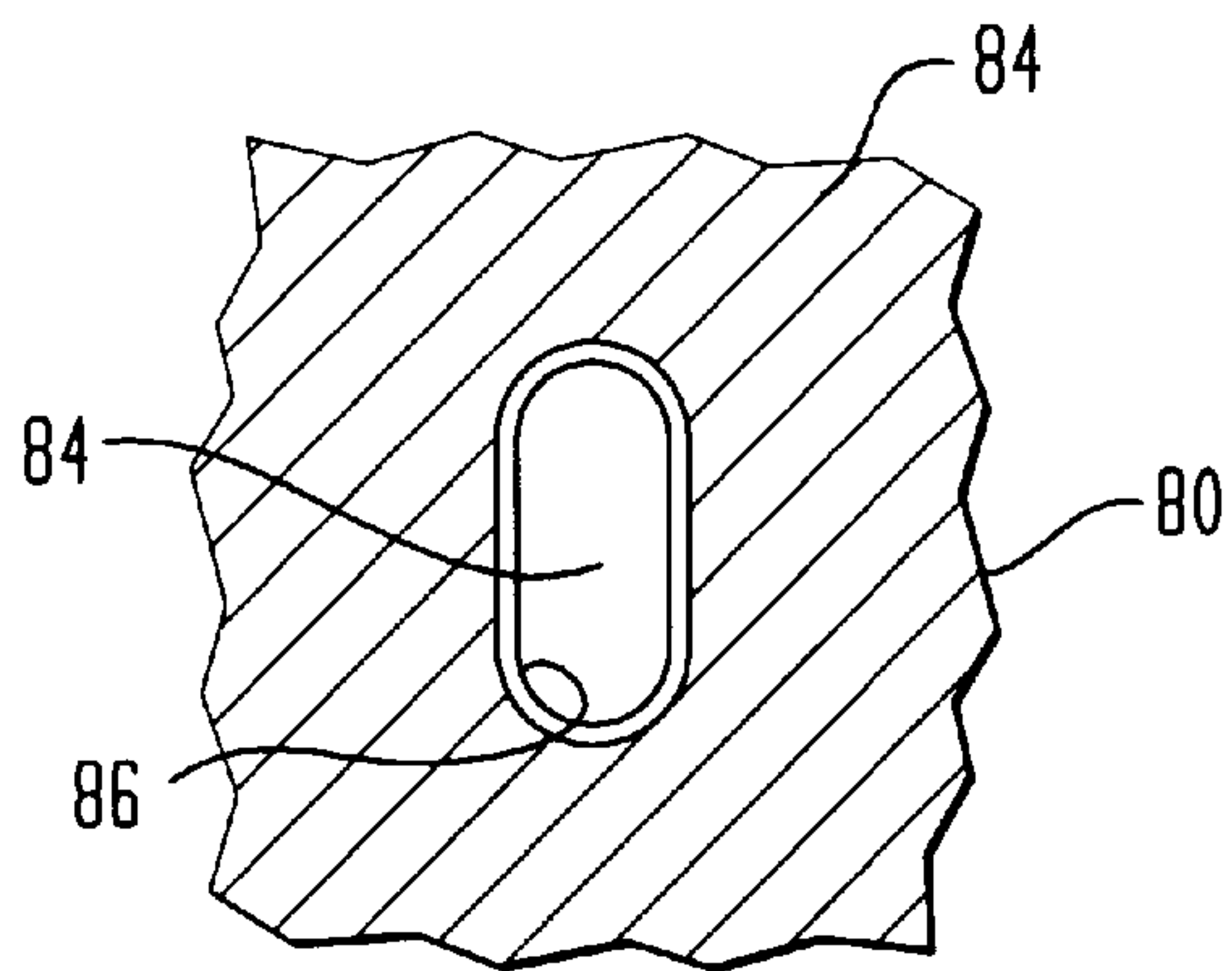


FIG. 5C

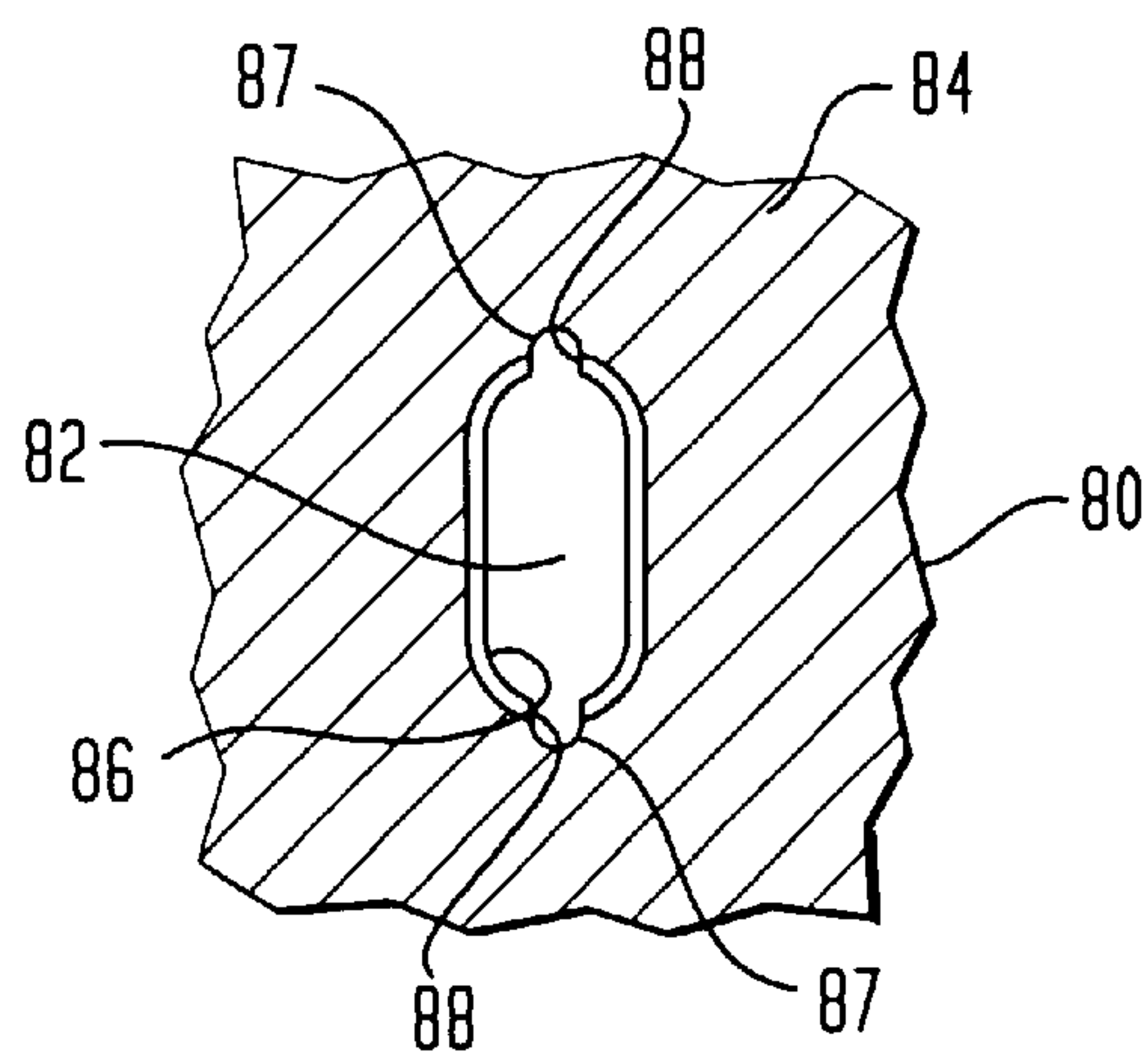


FIG. 5D

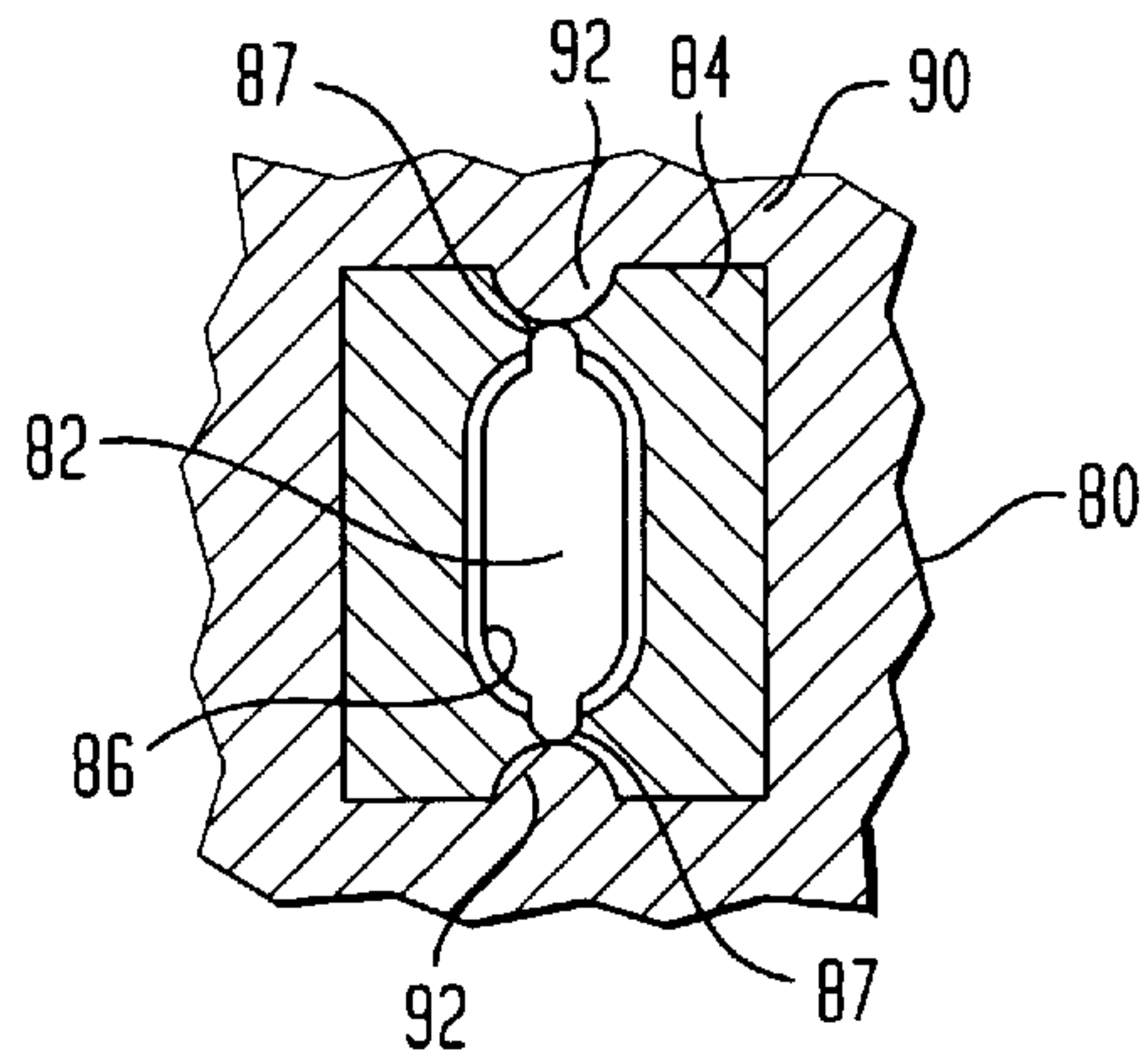


FIG. 5E

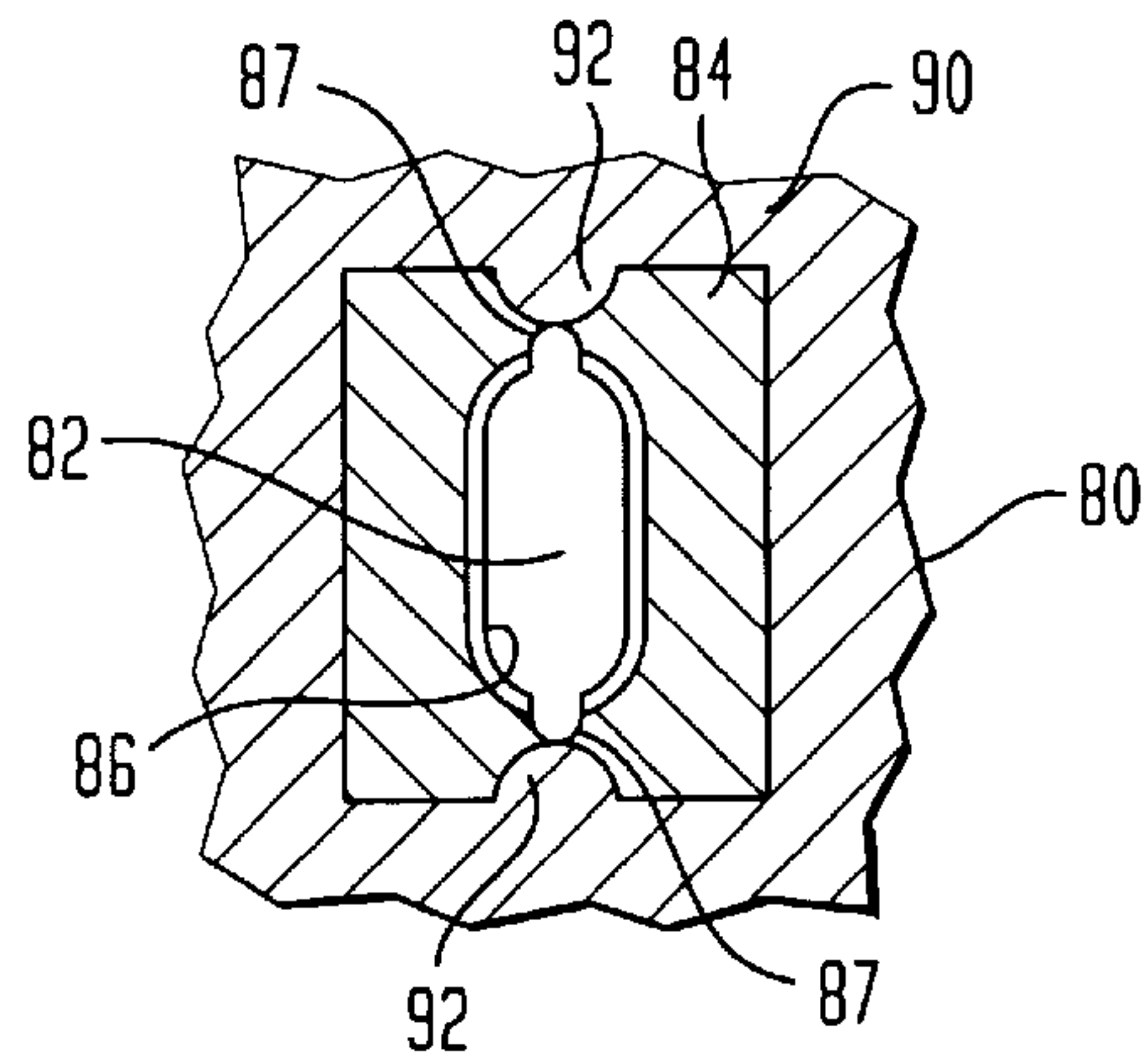


FIG. 5F

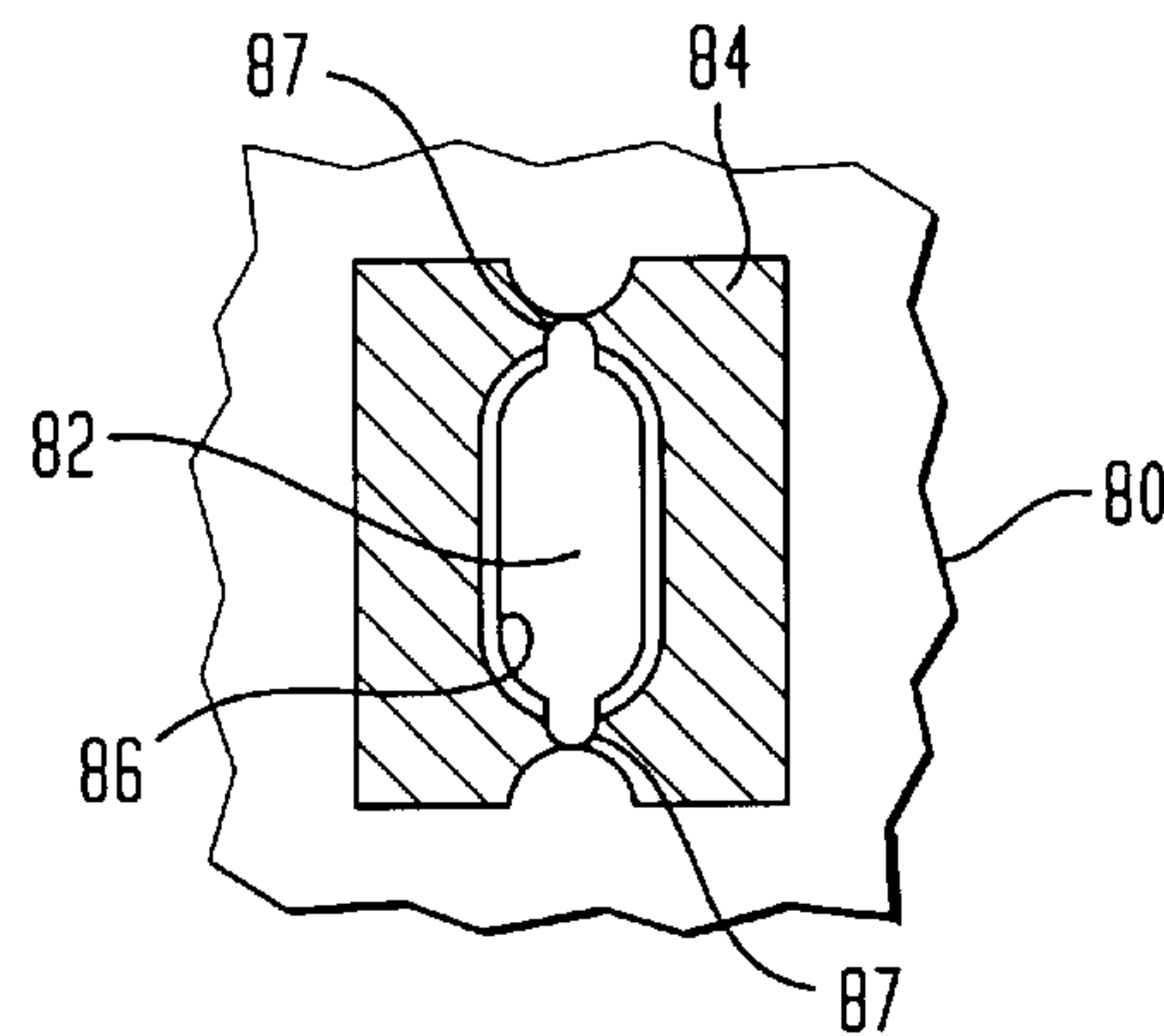
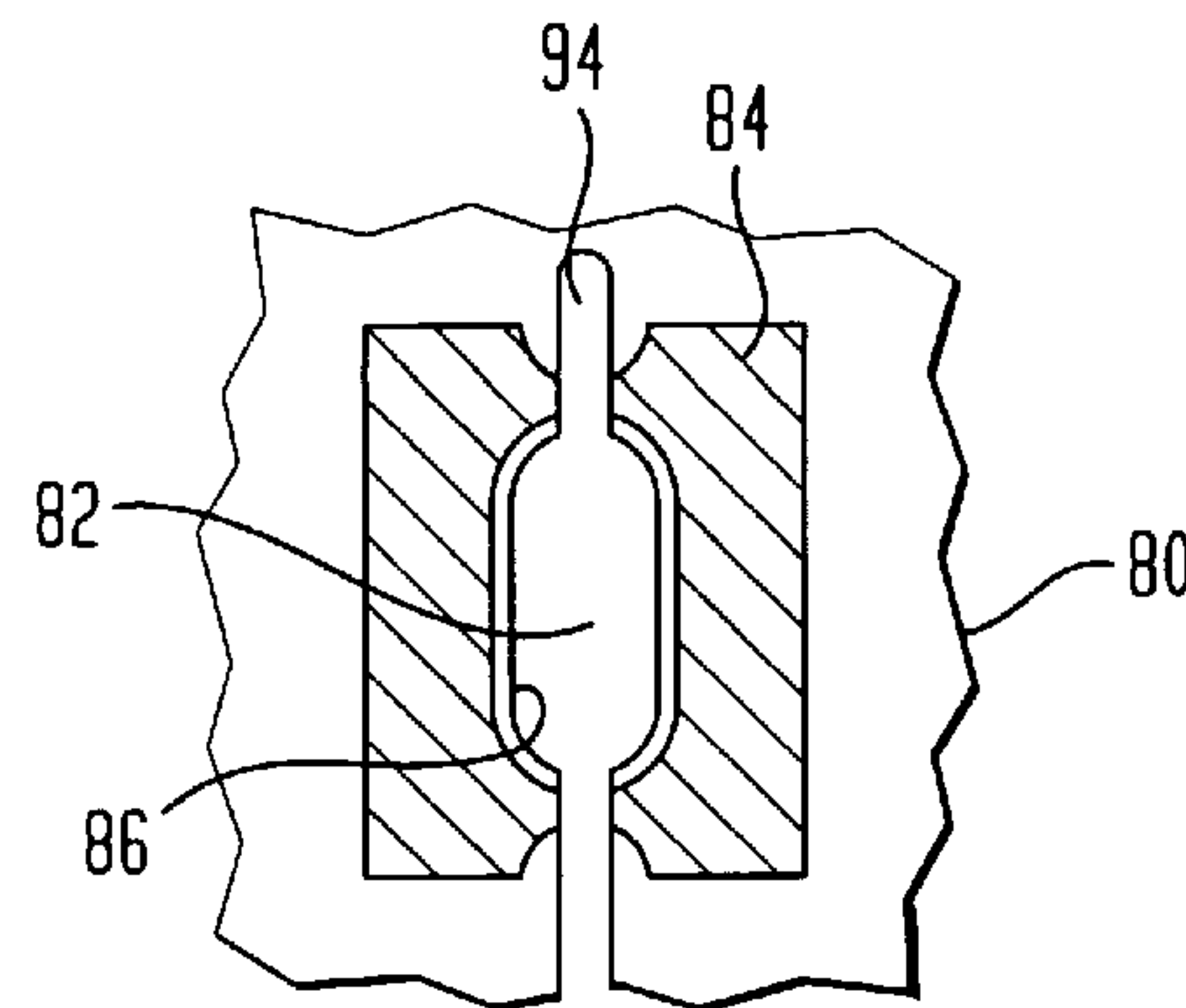


FIG. 5G



METHOD OF MAKING PERIPHERAL LOW INDUCTANCE INTERCONNECTS WITH REDUCED CONTAMINATION

FIELD OF THE INVENTION

This invention relates to methods of making circuit devices with peripheral low inductance interconnects, and in particular, to a method for making such interconnects with reduced contamination by conductive particulates. The method is particularly useful in making printed wiring board devices (PWBs).

BACKGROUND OF THE INVENTION

Circuit devices are used in a vast assortment of equipment including computers and communication systems. Many circuit devices include dense and complex arrays of electronic, magnetic, and/or electromagnetic circuit components such as capacitors, resistors, integrated circuit chips (ICs), inductors, and lens systems, mounted on a printed wiring board (PWB). The PWB mechanically supports the circuit components and electrically interconnects them.

PWBs also provide means for electrically interconnecting the devices to electrical power, ground and other circuit devices mounted on a motherboard. Such means typically comprise electrical interconnect structures which can include separately attached connectors or interconnects built directly into the PWB or motherboard.

Conventional electrical interconnects used for interconnecting circuit devices such as high-speed microprocessors and power supplies may produce undesirable switching transients, especially if large currents must be switched and delivered to the microprocessor in a high-speed manner. In such cases, the presence of even small inductances in the interconnection path can generate significant spurious voltage signals. Such signals can deleteriously affect the performance of the microprocessor. Lowering the inductance in the interconnection path reduces the magnitude of the spurious or transient signals. Accordingly, low-inductance interconnects are essential for assuring the performance of the microprocessor.

Electrical interconnects with appropriately low-inductance have been developed for such circuit devices. These interconnects are formed in the edge surface of the PWB and typically comprise thin layers of copper (Cu). The interconnects are formed by routing or cutting through specially metallized regions of the PWB during PWB manufacture. Routing produces metal burrs in the metallized regions which must be removed by de-burring the PWB.

Unfortunately, deburring can contaminate the PWB circuitry with metal debris and compromise the various coatings on the PWB. Additionally, electrical interconnects for high-current circuit devices are made with thicker layers of metal than interconnects for low-current devices and thus, have more severe burring/deburring problems.

Accordingly, a need exists for an improved method of making a circuit device with ultra-low inductance electrical interconnects.

SUMMARY

A method for making a circuit device having at least one peripheral interconnect for electrically connecting the device to another circuit device on a motherboard. The method comprises forming at least one opening in a substrate and coating the inner surface of the opening and portions of major surfaces of the substrate adjacent the

opening with electrically conductive material. Electrically conductive material is removed from opposing regions of the inner surface of the opening prior to plating and then, after plating, the substrate is cut in a line extending across opposing regions to expose the coated and plated inner surface as the peripheral electrical interconnect.

BRIEF DESCRIPTION OF THE DRAWINGS

The advantages, nature and various additional features of the invention will appear more fully upon consideration of the illustrative embodiments now to be described in detail in connection with the accompanying drawings wherein:

FIG. 1 is a perspective view of a circuit device having a plurality of ultra-low inductance electrical interconnects;

FIG. 2A is a plan view of an ultra-low inductance electrical interconnect which is similar to the interconnects depicted in FIG. 1;

FIG. 2B is an elevational view of the interconnect of FIG. 2A;

FIG. 3A is a plan view of a second type of ultra-low interconnect;

FIG. 3B is an elevational view of the interconnect of FIG. 3A;

FIGS. 4A, 4B, 4C, 4D, 4E, 4F, and 4G are plan views of a segment of a PWB illustrating a process for forming a circuit device having an ultra-low inductance electrical interconnect similar to the electrical interconnect shown in FIGS. 2A and 2B; and

FIGS. 5A, 5B, 5C, 5D, 5E, 5F, and 5G are plan views of a segment of a PWB illustrating a second process for forming a circuit device having an ultra-low inductance electrical interconnect similar to the electrical interconnect shown in FIGS. 3A and 3B.

It is to be understood that these drawings are for purposes of illustrating the concepts of the invention and, except for graphical illustrations, are not to scale.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 illustrates a circuit device **10** having a plurality of ultra-low inductance electrical interconnects **16**. The circuit device **10** comprises a printed wiring board **12** (PWB) with circuit components **14** mounted thereon and the electrical interconnects **16** disposed along the edge surfaces of the PWB **12**. The interconnects **16** are especially useful for power module circuit devices and power hybrid package circuit devices requiring low-inductance electrical interconnection paths to associated circuit devices on a motherboard. The ultra-low interconnects **16** may also be used in other applications where low-inductance electrical interconnection paths are required.

FIGS. 2A and 2B show an ultra-low inductance electrical interconnect **20** similar to the electrical interconnects depicted in FIG. 1. The interconnect **20** comprises a stepped recess **22** defined in the edge surface **26** of a double-sided PWB **24**, electrically conductive metallic plates **28** (horizontal plates **28**) extending from the stepped recess **22** on at least the upper and lower surfaces of the PWB **24** and an electrically conductive metallic plate **30** (vertical plate **30**) extending between the horizontal plates **28** along a surface of the stepped recess **22**. Each horizontal plate **28** has a narrowed region **32** that tapers inwardly toward the stepped recess **22**. The narrowmost portion **34** of the narrowed region **32** of each horizontal plate **28** extends slightly beyond the stepped recess **22** along the edge of the PWB **24**.

The metallic plates **28, 30** of the interconnect **20** typically comprise copper (Cu). The metallic plates of low current interconnects typically comprise about 0.5–1.0 ounces of Cu (about 0.69–1.38 mils thick) and the plates of high current interconnects typically comprise about 2–4 ounces of Cu (about 2.8–5.5 mils thick).

FIGS. **3A** and **3B** show a second type of ultra-low inductance electrical interconnect **40**. This interconnect **40** is substantially similar to the interconnect **20** described with respect to FIGS. **2A** and **2B**. However, the narrowmost portion **48** of the horizontal plate's **44** narrowed region **46** does not extend beyond the stepped recess **42**.

FIGS. **4A–4G** illustrate a process for forming circuit devices with ultra-low inductance electrical interconnects similar to the interconnects shown in FIGS. **2A** and **2B**.

In the first step of the process shown in FIG. **4A**, a double-sided PWB **50** coated with a metallic flash **52**, is drilled and deburred to provide one or more holes or vias **54** (only one shown). The hole **54** can be elongated as shown, or circular. The hole **54** extends entirely through the PWB **50** and can be formed with a suitable drilling and deburring apparatus. The metallic flash **52** typically comprises a thin layer of Cu.

FIG. **4B** shows the PWB **50** after the inner surface of the elongated hole **54** has been coated with a metallic flash **56**. This metallic flash **56** can be a thin layer of Cu or other metal. The metallic flash **56** is typically applied to the surface of the elongated hole **54** by an electroless plating bath, by sputtering, or by chemical vapor deposition.

The next step of the process shown in FIG. **4C** comprises notching or “pre-routing” the ends of the elongated hole **54** to provide the hole with opposing notches **60**. The notches **60** provide the hole **54** with inner surface portions **58** that are not coated with the metallic flash **56**. (The notches **60** and the elongated hole **54** define the stepped recess portion of the interconnect.) Because the inner surfaces **58** of the notches **60** have no metallic flash, metallic material buildup in this region is advantageously prevented during subsequent interconnect processing. Pre-routing can be accomplished with a suitable routing apparatus.

FIG. **4D** shows the PWB **50** after increasing the thickness of the metallic flash **56, 52** respectively coating the elongated hole **54** and the surfaces of the PWB **50**. This is typically accomplished by electrolytically plating the PWB **50**.

An etch mask **62** is formed over the elongated hole **54** in the fifth step of the process as shown in FIG. **4E**. The etch mask **62** tapers toward the notches **60** of the hole **54** at locations denoted by numerals **64** and **66** to minimize or restrict the area of metallization **52** covered in these regions while providing adequate “tenting” for future etching. The etch mask **62** typically comprises a patterned layer of photoresist. The photoresist layer is about 2.7 mils thick and can be formed using conventional photolithography.

FIG. **4F** shows the PWB **50** after etching the unmasked portions of the metallic layer **52** and stripping away the etch mask **62**. This step is typically performed using conventional metal etching and resist removal processes. Narrow strips **68** of metallization remain adjacent the notches **60** of the hole **54**.

The circuit device and the interconnect are finalized in the step shown in FIG. **4G** which comprises applying a soldermask, cutting or routing the PWB **50** along a routing path **70** that extends through the notches **60** and the narrow metallization strips **68**, and mounting circuit components (not shown) on the PWB **50**. Because the routing path **70**

extends through the notches **60** and the narrow strips **68** of metallization, burring is minimized. In particular, virtually no burring occurs in the region defined by the notches **60** and burring is minimized in the cut-through region of the narrow metallization strips **68**. Accordingly, subsequent deburring operations are advantageously minimized.

FIGS. **5A–5G** illustrate a process for forming a circuit device having an ultra-low inductance electrical interconnect similar to the electrical interconnect shown in FIGS. **3A** and **3B**. This process can also produce a circuit device having multiple ultra-low inductance electrical interconnects.

The process starts off with an uncoated double-sided PWB **80**. In FIG. **5A**, the uncoated PWB **80** is drilled and deburred to provide an elongated hole **82**.

In the second step of the process shown in FIG. **5B**, the inner surface of the elongated hole **82** and the surfaces of the PWB **80** are coated with a metallic flash **86, 84** such as Cu. This step can be performed using electroless plating, sputtering, or CVD.

The next step of the process shown in FIG. **5C**, comprises notching or pre-routing the ends of the elongated hole **82** to provide notches **87** with inner surface portions **88** that are not coated with the metallic flash. This process step is substantially similar to the process step of FIG. **4C**.

FIG. **5D** shows a mask layer **90** of photoresist formed partially over each surface of the PWB **80**. The mask layer **90** includes two projections **92** which extend toward the edges of the notches **87**.

In FIG. **5E**, the thickness of the metallic flash **82, 86** covering the unmasked surfaces of the PWB **80** and the inner surface of the elongated hole **84** is increased by electrolytically plating (with Cu) and solder/tin plating the PWB **80**. The projections **92** of the mask layer **90** prevent plating material from being deposited adjacent the ends of the notches **87**. Note that no plating takes place in region **88**.

FIG. **5F** shows the PWB **80** after stripping away the mask layer **90** and then etching the PWB **80** to remove the unplated portions of the metallic flash **86** (the solder/tin plating resists the etching). As shown, no metallic material remains at the ends of the notches **87**.

The final step of the process shown in FIG. **5G** comprises applying a soldermask, cutting or routing the PWB along a routing path **94** that extends through the notches **87**, and mounting circuit components (not shown) to the PWB **80** to finalize the circuit device and the structure of the interconnect. The routing path **94** does not extend through any metallization. Accordingly, subsequent deburring operations are minimized or eliminated because substantially no burrs are created during this step.

It can now be seen that the improved method of making a circuit device having one or more peripheral electrical interconnects modifies conventional processes. An important modification is that the flash coating of the opening inner surface is removed from at least two regions of the inner surface before plating. The removal can be affected by removing portions of the substrate adjacent the opening, as by routing. This removal prevents plating on the regions, and this eliminates cutting of conductive material when the substrate is cut to expose the plated portions of the inner surface.

It can also be seen that in relation to the direction of cutting (across the opening between the regions of removed coating) there are advantageous dimensional relations. If transverse to the cutting direction, the opening has a dimen-

sion d_1 , the maximum dimension regions of the removed coating have a dimension of d_2 , and the width of cutting has a dimension d_3 , then d_3 should be less than d_2 , and d_3 should be less than d_1 . d_2 is not necessarily less than d_1 .

The improved method can be applied to insulating substrates, to insulating substrates having conductive layers on one or both major surfaces, and to multilayer substrates comprising plural insulating layers sandwiching one or more internal conductive layers. Preferably the internal conductive layers are patterned so that they do not cross the line of cutting.

The flash coating is typically electroless coated to a thickness less than about 10 micrometers and plating is typically electrolytic plating to a thickness greater than about 20 micrometers. Copper is the preferred conductive material.

While the foregoing invention has been described with reference to the above embodiments, various modifications and changes may be made without departing from the spirit of the present invention. Accordingly, modifications and changes such as those suggested above but not limited thereto are considered to be within the scope of the claims.

What is claimed is:

1. In the method of making a circuit device including at least one peripheral electrical interconnect comprising the steps of a) providing a planar substrate having first and second major surfaces, b) forming in the substrate an opening having an opening inner surface extending between the first and second major surfaces, c) applying to the opening inner surface a flash coating of electrically conductive material, d) plating additional conductive material in the opening, e) cutting across the opening to expose the plated inner surface as the peripheral electrical interconnect;

the improvement wherein:

after flash coating the opening inner surface and before plating, flash coating is removed from at least two regions of the inner surface to prevent plating on said regions; and the cutting across the opening extends between the two regions of coating removal to reduce the cutting of conductive material.

2. The method of claim 1 wherein the flash coating is removed from the inner surface by removing portions of the substrate adjacent the opening.

3. The method of claim 1 wherein the flash coating is removed from the inner surface by routing portions of the substrate adjacent the opening.

4. The method of claim 1 wherein the cutting across the opening is by routing.

5. The method of claim 1 wherein transverse to the direction of cutting across the opening, the opening has a dimension d_1 , the maximum dimension of the removed coating has a dimension of d_2 , and the width of cutting has a dimension d_3 , wherein d_3 is less than d_2 , and d_3 is less than d_1 .

6. The method of claim 1 wherein the flash coating comprises copper.

7. The method of claim 1 wherein the plated conductive material comprises copper.

8. The method of claim 1 wherein providing the substrate comprises providing an insulating substrate.

9. The method of claim 1 wherein providing the substrate comprises providing an insulating substrate including a layer of conductive material on at least one major surface.

10. The method of claim 1 wherein providing the substrate comprises providing a multilayer substrate comprising a plurality of insulating layers and one or more internal layers of conductive material.

11. The method of claim 1 including the step of connecting the circuit device to another circuit device through the peripheral electrical interconnect.

12. A method for making a circuit device having at least one peripheral interconnect for electrically connecting the device to another circuit device, the method comprising the steps of:

providing a planar substrate having first and second major surfaces;

forming at least one opening in the substrate, the opening having an inner surface extending between the first and second major surfaces;

coating the inner surface of the opening and portions of the major surfaces adjacent the opening with electrically conductive material;

removing the electrically conductive material from opposing regions of the inner surface of the opening; after said removing, plating additional conductive material in the opening; and

cutting the substrate in a line extending across opposing regions to expose the plated inner surface as the peripheral electrical interconnect.

13. A circuit device comprising a peripheral interconnect made by the process of claim 1.

* * * * *